

Abstracts of Technical Articles by Bell System Authors

*Investigation of Oxidation of Copper by Use of Radioactive Cu Tracer.*¹ J. BARDEEN, W. H. BRATTAIN, and W. SHOCKLEY. A very thin layer of radioactive copper was electrolytically deposited on a copper blank. The surface was then oxidized in air at 1000°C for 18 minutes, giving an oxide layer with a thickness of 1.25×10^{-2} cm. After quenching, successive layers of the oxide were removed chemically, and the copper activity in each layer was measured. The observed self-diffusion of radioactive copper in the oxide agrees quantitatively with a theory based on the following assumptions: (a) The oxide grows by diffusion of vacant Cu^+ sites from the outer surface of the oxide inward to the metal. (b) The concentration of vacant sites at the oxygen-oxide interface is independent of the oxide thickness, and drops linearly from this constant value to zero at the metal boundary. (c) Accompanying the inward flow of vacant sites, there is a flow of positive electron holes such as to maintain electrical neutrality. (d) Self-diffusion of copper ions takes place only by motion into vacant sites. The results give a fairly direct confirmation of the theory of oxidation first suggested by Wagner.

*A New Magnetic Material of High Permeability.*² O. L. BOOTHBY and R. M. BOZORTH. This paper describes the preparation, heat treatment, and properties of *supermalloy*, a magnetic alloy of iron, nickel, and molybdenum. In the form of 0.014 in. sheet it has an initial permeability of 50,000 to 150,000, a maximum permeability of 600,000 to 1,200,000, coercive force of 0.002 to 0.005 oersted, and a hysteresis loss of less than 5 ergs/cm³/cycle at $B = 5000$. Transformer cores made of insulated 0.001 in. tape, spirally wound, have about the same initial permeability and a maximum permeability of 200,000 to 400,000. The alloy has a Curie point of 400°C and appears to have an order-disorder transformation temperature somewhat above 500°C.

*Magnetoresistance and Domain Theory of Iron-Nickel Alloys.*³ R. M. BOZORTH. Measurements of change of electrical resistivity with magnetization and with tension are reported for iron-nickel alloys containing 40 to 100 per cent nickel. When the magnetostriction is negative (81 to 100 per

¹ *Jour. of Chemical Physics*, December 1946.

² *Jour. Applied Physics*, February 1947.

³ *Phys. Rev.*, Dec. 1 and 15, 1946.

cent nickel), tension (σ) decreases resistivity, and magnetic field (H) increases it. Domain theory predicts the ratio σ/H at which the resistivity is equal to that of the unmagnetized specimen, and the theory is accurately confirmed. Measurements are made in transverse as well as longitudinal magnetic fields, and the difference between the resistances so measured is shown to be independent of the distribution of domains in the unmagnetized state; the erratic results reported in the literature are thus explained and avoided. When magnetostriction is positive, the limiting changes of resistivity with field and tension are sometimes found to be different; this is shown to be caused by the variation of magnetostriction with crystallographic direction.

*A Wide-Tuning-Range Microwave Oscillator Tube.*⁴ JOHN W. CLARK and ARTHUR L. SAMUEL. This paper describes a reflex-type velocity-variation oscillator tube with a wide tuning range in the microwave band. The tube will oscillate from 2000 to 13,000 megacycles, but practical tuning considerations limit the band in any one circuit to a two-to-one frequency range. The problems involved in the design and a description of the various elements are given.

*Accelerated Ozone Weathering Test for Rubber.*⁵ JAMES CRABTREE and A. R. KEMP. Light-energized oxidation and cracking by atmospheric ozone are the agencies chiefly responsible for the deterioration of rubber outdoors. Since these processes are separate and distinct, it is proposed to distinguish between them in the evaluation of rubber for resistance to weathering. An accelerated test for susceptibility to atmospheric ozone cracking is discussed. Apparatus for conducting the test and for measurement of ozone in minute concentration is described in detail.

*Measurements in Communications.*⁶ N. B. FOWLER. For convenient reference, some of the more common measurement units and scales used in communication engineering are presented in tabular form together with supplementary explanatory text. Included in the table, which also indicates the limitations involved, are quantities used in measuring power, volume, circuit noise, sound, light, radio fields, crosstalk coupling, and certain other transmission concepts.

*An Improved 200-Mil Push-Pull Density Modulator.*⁷ J. G. FRAYNE, T. B. CUNNINGHAM and V. PAGLIARULO. A completely new variable-

⁴ *Proc. I.R.E. and Waves and Electrons*, January 1947.

⁵ *Indus. & Engg. Chemistry, Analytical Edition*, December 1946.

⁶ *Electrical Engineering*, February 1947.

⁷ *Jour. S.M.P.E.*, December 1946.

density modulator utilizing a three ribbon push-pull valve is described. The entire valve is sealed by the force of the Alnico V permanent magnet on the Permendur pole pieces. Signal is applied to the center ribbon and noise-reduction currents are applied to the outer ribbons. True class A push-pull operation is obtained from the two component single ribbon valves by the use of an inverter prism which aligns the modulating and noise-reduction edges of each aperture.

An anamorphote condenser lens is used to eliminate lamp filament striations at the valve ribbon plane. An anamorphote objective lens gives a 4:1 reduction of the valve aperture in the vertical plane at the film and a 2:1 reduction along the length of the sound track. A meter is supplied to measure exposure as well as setting up "bias." A photocell monitor is supplied and a "blooming" light for indicating synchronous start marks.

Mathematical analysis of the exposure produced by the modulating ribbon is appended as well as a similar analysis of the four ribbon push-pull valve which the new valve supersedes.

*Factors Governing the Intelligibility of Speech Sounds.*⁸ N. R. FRENCH and J. C. STEINBERG. The characteristics of speech, hearing, and noise are discussed in relation to the recognition of speech sounds by the ear. It is shown that the intelligibility of these sounds is related to a quantity called articulation index which can be computed from the intensities of speech and unwanted sounds received by the ear, both as a function of frequency. Relationships developed for this purpose are presented. Results calculated from these relations are compared with the results of tests of the subjective effects on intelligibility of varying the intensity of the received speech, altering its normal intensity-frequency relations and adding noise.

*Short Duration Auditory Fatigue as a Method of Classifying Hearing Impairment.*⁹ MARK B. GARDNER. Earlier studies have classified deafness cases into two general groups, those having functional disorders of the middle ear and those having impairments resulting from atrophy of the nerve fibers terminating along the basilar membrane (conductive and nerve deafness types, respectively). Such classifications have been made using bone conduction threshold measurements and unilateral loudness balance results as the basis for differentiation. Bone conduction results, however, are often subject to considerable error while the unilateral loudness balance technique can only be applied to individuals having one normal and one impaired ear. These limitations introduce a need for a completely independent monaural method of classifying deafness types. This is particularly true for the selec-

⁸ *Jour. Acous. Soc. Amer.*, January 1947.

⁹ *Jour. Acous. Soc. Amer.*, January 1947.

tion of candidates suitable for the fenestration operation for the restoration of hearing in otosclerosis (immobilized stapes). The present paper is concerned with an investigation of short time auditory fatigue as a method of obtaining an impairment analysis. In this study, it was found that the fatigue of the conductively deafened observer was similar to the normal observer except the onset of fatigue was shifted by the amount of the threshold loss. For the nerve deafened observer, on the other hand, the onset of fatigue was found to occur at normal intensity levels. The occurrence of excessive fatigue in one of the nerve type impairment cases investigated appears to offer additional information on the nature of the lesion.

*A Sampling Procedure for Design Tests of Electron Tubes (Sponsored by Joint Electron Tube Engineering Council).*¹⁰ S. W. HORROCKS, P. M. DICKERSON, H. F. DODGE,* E. R. OTT, H. G. ROMIG,* W. B. RUPP, J. R. STEEN, R. E. WAREHAM, AND A. K. WRIGHT. The Committee on Sampling Procedure was established on July 21, 1943 as part of the Electron Tube Section of the Radio Manufacturers Association (RMA). The purpose of the Committee is to develop sampling methods and to act in an advisory capacity towards standardization of Sampling Procedures throughout the Electron Tube industry. This Committee was later embodied as a main Committee of the Joint Electron Tube Engineering Council of the RMA and NEMA. This Council was established in 1945 to handle all engineering matters for the Electron Tube industry for both trade associations, Radio Manufacturers Association and National Electrical Manufacturers Association.

One of the earliest projects handled by the Committee was the development of a statistically sound sampling inspection procedure for so-called "design tests" of electron tubes. In general, design tests relate to characteristics that are normally quite stable and are relatively less important to the consumer. The nature of these tests is such that only relatively small samples are practicable. The Joint Army-Navy Specification JAN-1A incorporated a sampling plan for design tests allowing (1) not more than 10% of the sample tubes to contain design test defects of any one kind and (2) not more than 20% of the sample tubes to contain design test defects of any kind. Because of the extremely wide range in lot sizes for different classes of electron tubes, such a simplified sampling plan was in effect too strict for small lot sizes and too liberal for large lot sizes. Moreover, no distinction was made in the relative seriousness of different kinds of design test defects. The Committee accordingly set about to prepare a sampling inspection plan that would be relatively free of these faults. The new procedure covers all

¹⁰ *Industrial Quality Control*, November 1946.

* *Of Bell Tel. Labs.*

aspects of the acceptance problem and provides an operationally definite criterion for reducing inspection for a product whose quality is regularly well controlled within the intent of the specification.

The procedure developed by the Committee was approved by J.E.T.E.C. (Joint Electron Tube Engineering Council), was approved by the JAN Committee in September 1945, and is reproduced in full in this article. It will be noted that the procedure provides for two Acceptable Quality Levels (AQL), namely 6% defective and 3% defective for individual design test characteristics. Each design test of a particular type of electron tube is classified as either a Standard Design Test with an AQL = 6% or a Special Design Test with an AQL = 3%. For any design test, if product submitted for inspection has quality equal to the AQL, the chances of acceptance are of the order of 94 to 98 out of 100. If quality runs consistently better than the AQL, reduced inspection is permitted, thus serving as an incentive for the manufacturer to strive for better quality. The operating characteristics of the sampling plans involved are appended to this article and show the degree to which the plans will discriminate for various levels for submitted quality.

*Resonant Circuit Modulator for Broad Band Acoustic Measurements.*¹¹

GORDON FERRIE HULL, JR.* A modulation method is described whereby a broad band frequency response is obtained for recording of sound. In particular low frequency sound approaching zero c.p.s. can be recorded. The theory of the resonant circuit modulating principle is first discussed followed by a description of the apparatus which was constructed for this purpose.

*Quality Reporting—Putting Inspection Results to Work.*¹² HAROLD R. KELLOGG. Quality reporting is an integral part of the general inspection problem. It cannot be divorced from the logic and aims of an overall inspection program. A discussion of quality reporting should therefore include consideration of (1) inspection procedures, including the collection of data; (2) appraisal of the data; (3) reporting and publicizing results. This outlines the program as it is discussed in this paper.

*Properties of Monoclinic Crystals.*¹³ W. P. MASON. Two crystals of the monoclinic sphenoidal class have been found which have modes of vibration with zero temperature coefficients of frequency, and this property together

¹¹ *Jour. Applied Physics*, December 1946.

* This research was carried out while the author was a member of the Technical Staff of the Bell Telephone Laboratories, Inc., Murray Hill, New Jersey.

¹² *Industrial Quality Control*, November 1946.

¹³ *Phys. Rev.*, Nov. 1 and 15, 1946.

with the high electromechanical coupling and the high Q 's make it appear probable that these crystals may have considerable use as a substitute for quartz which is difficult to obtain in large sizes. These crystals are ethylene diamine tartrate ($C_6H_{14}N_2O_6$) and dipotassium tartrate ($K_2C_4H_4O_6, \frac{1}{2}H_2O$). Complete measurements of the elastic, piezoelectric, and dielectric constants of the dipotassium tartrate (DKT) crystal are given in this paper. The crystal has 4 dielectric constants, 8 piezoelectric constants, and 13 elastic constants. A discussion is given in the appendix of the method of measuring these constants by the use of 18 properly oriented crystals.

*An Acoustic Constant of Enclosed Spaces Correlatable with Their Apparent Liveness.*¹⁴ J. P. MAXFIELD and W. J. ALBERSHEIM. An acoustic constant called liveness is derived, which constant is correlatable with the acoustic properties of the enclosed space and with the distance between the sound source and the listener. This constant represents the ratio of a time integral of the energy density of the reverberant sound to the unintegrated energy density of the direct sound. The validity of this constant is substantiated by empirical data. Certain subjective effects of monaurally reproduced sounds as a function of the liveness of its pick-up conditions are briefly discussed.

*Directional Couplers.*¹⁵ W. W. MUMFORD. The directional coupler is a device which samples separately the direct and the reflected waves in a transmission line. A simple theory of its operation is derived. Design data and operating characteristics for a typical unit are presented. Several applications which utilize the directional coupler are discussed.

*Theory of the Beam-Type Traveling-Wave Tube.*¹⁶ J. R. PIERCE. The small-signal theory of the beam traveling-wave tube has been worked out. The equations predict three forward waves, one increasing and two attenuated, and one backward wave which is little affected by the electron stream. The waves are partly electromagnetic and partly disturbance in the electron stream. The dependence of the wave propagation coefficients on voltage, current, circuit loss, and the other properties of the transmission mode which propagates energy and the cut-off transmission modes is given. Expressions for gain and noise figure and an estimate of power output are given. Appendix A gives an expression for the field in a uniform transmission system due to impressed current (as, of an electron stream) in terms of the parameters of the transmission modes. Appendix B calculates the propagation

¹⁴ *Jour. Acous. Soc. Amer.*, January 1947.

¹⁵ *Proc. I.R.E.*, February 1947.

¹⁶ *Proc. I.R.E.*, February 1947.

constant and the field for unit power flow for the gravest mode of helical transmission system.

*Traveling-Wave Tubes.*¹⁷ J. R. PIERCE and L. M. FIELD. Very-broad-band amplification can be achieved by use of a traveling-wave type of circuit rather than the resonant circuit commonly employed in amplifiers. An amplifier has been built in which an electron beam traveling with about $1/13$ the speed of light is shot through a helical transmission line with about the same velocity of propagation. Amplification was obtained over a bandwidth 800 megacycles between 3-decibel points. The gain was 23 decibels at a center-band frequency of 3600 megacycles.

*Attenuation of Forced Drainage Effects on Long Uniform Structures.*¹⁸ ROBERT POPE. When forced drainage is applied to an underground metallic structure to provide cathodic protection, the greatest effects on the structure and earth potentials occur in the vicinity of the drainage point and anode. These effects taper off as the distance from the drainage point increases and even in the relatively simple case of a long, uniform structure, the manner in which these effects taper off or attenuate is quite complex. However, by making a few justifiable assumptions, relatively simple equations are developed which provide sufficiently accurate results in most practical cases. Furthermore, the simple equations bring out more clearly the relative importance of the various factors involved than do the more rigorous equations. The approximate equations have been used with fair success in predicting the effects of drainage on underground telephone cables in conduit and on buried coated cables. They should apply quite accurately to coated pipes, and there are examples of reasonably good application on some bare pipes.

The soil and structure characteristics which enter into the equations are discussed, and the units used established.

*Alkaline Earth Porcelains Possessing Low Dielectric Loss.*¹⁹ M. D. RIGTERINK and R. O. GRISDALE. Alkaline earth porcelains have been prepared from mixtures of clay, flint, and synthetic fluxes consisting of clay calcined with at least three alkaline earth oxides. These porcelains possess excellent dielectric properties, have low coefficients of thermal expansion, are white, and are especially valuable as bases for deposited carbon resistors for which they were developed. Their characteristics make it probable that other uses will be found for materials of this type.

An illustrative composition is 50.0% Florida kaolin, 15.0% flint (325

¹⁷ *Proc. I.R.E.*, February 1947.

¹⁸ *Corrosion*, December 1946.

¹⁹ *Jour. Amer. Ceramic Soc.*, March 1, 1947.

mesb), 35.0% calcine (200 mesb). The composition of the calcine is 40.0% Florida kaolin, 15.0% MgCO_3 , 15.0% CaCO_3 , 15.0% SrCO_3 , 15.0% BaCO_3 , calcined at 1200°C. The electrical properties of this body at 1 mc. are Q at 25°C, 2160; Q at 250°C, 280; Q at 350°C, 90; specific resistance at 150°C, $10^{13.5}$ ohm-cm. and at 300°C, $10^{10.7}$ ohm-cm.

*A Coaxial-Type Water Load and Associated Power-Measuring Apparatus.*²⁰ R. C. SHAW and R. J. KIRCHER. This paper presents a description of a coaxial-type water load and associated equipment suitable for measuring peak pulse powers of the order of a megawatt. Water-cell loads have been designed to operate at wavelengths of from 10 to 40 centimeters, where the average dissipation is of the order of 300 watts. Ordinary tap water is used in the load to dissipate the radio-frequency power.

*The Ammonia Spectrum and Line Shapes Near 1.25-cm Wave-Length.*²¹ CHARLES HARD TOWNES. The ammonia "inversion" lines near 1.25-cm wave-length are resolved, their widths being decreased at low pressures to 200 kilocycles. Line shapes, intensities, and frequencies are measured and correlated with theory. Calculated intensities and Lorentz-type broadening theory fit experimental results if frequency of collision is fifteen times greater than that measured by viscosity methods. Splitting due to rotation is in fair agreement with a recalculation of theoretical values. A saturation effect is observed with increase of power absorbed per molecule and an interpretation made.

*Non-Uniform Transmission Lines and Reflection Coefficients.*²² L. R. WALKER and N. WAX. A first-order differential equation for the voltage reflection coefficient of a non-uniform line is obtained and it is shown how this equation may be used to calculate the resonant wave-lengths of tapered lines.

*Temperature Coefficient of Ultrasonic Velocity in Solutions.*²³ G. W. WILLARD. Extensive measurements have been made, at ten megacycles, of the temperature dependence of ultrasonic velocity in liquids and liquid mixtures. All single liquids tested, except water, were found to have large negative temperature-coefficients in the temperature range of zero to 80°C. Water has a large positive coefficient at room temperature, decreasing to zero at 74°C and then becoming negative (with a peak velocity of 1557

²⁰ *Proc. I.R.E. and Waves and Electrons*, January 1947.

²¹ *Phys. Rev.*, Nov. 1 and 15, 1946.

²² *Jour. Applied Physics*, December 1946.

²³ *Jour. Acous. Soc. Amer.*, January 1947.

meters/sec). Solutions in water of various other liquids (and of some solids) give parabolic velocity *vs.* temperature curves like that for water but with the peak velocity and peak temperature values shifting with the concentration of the solution. In general increasing the concentration raises the peak velocity slightly and lowers the peak temperature markedly from the values for water alone. It has also been found possible by compounding three-component solutions to adjust the values of the peak velocity and peak temperature independently within a narrow range of velocities and a wide range of temperatures.

*Measurements of Ultrasonic Absorption and Velocity in Liquid Mixtures.*²⁴ F. H. WILLIS. The absorption (α) and velocity (V) of sound in liquid mixtures were measured at four frequencies (ν) in the range 3.8 to 19.2 mc, using the Debye-Sears-Lucas-Biquard optical technique improved by the addition of a differential photoelectric cell indicator. This improvement permitted the use of lower sound intensities together with a wider sound beam than in the visual extinction method, thus improving conditions with respect to cavitation and beam distortion. In the mixtures investigated, α/ν^2 was found to be independent of frequency within the accuracy of the method, and there was no measurable dispersion of acoustic velocity. An absorption peak at intermediate concentrations not shifting with frequency was found in mixtures of acetone and water, and of ethyl alcohol and water, but was not in evidence in mixtures of acetone and ethyl alcohol, and of glycerol and water. The absorption peaks await theoretical explanation.

*Measuring Inter-Electrode Capacitances.*²⁵ C. H. YOUNG. New bridge, developed for measurement of extremely small values in high frequency tubes, useful to two-billionths of a microfarad.

²⁴ *Jour. Acous. Soc. Amer.*, January 1947.

²⁵ *Tele-Tech*, February 1947.